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*Article*

# Visions, Scenarios and Action Plans Towards Next Generation Tanzania Power System

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**Abstract:** This paper presents strategic visions, scenarios and action plans for enhancing Tanzania Power Systems towards next generation Smart Power Grid. It first introduces the present Tanzanian power grid and the challenges ahead in terms of generation capacity, financial aspect, technical and non-technical losses, revenue loss, high tariff, aging infrastructure, environmental impact and the interconnection with the neighboring countries. Then, the current initiatives undertaken by the Tanzania government in response to the present challenges and the expected roles of smart grid in overcoming these challenges in the future with respect to the scenarios presented are discussed. The developed scenarios along with visions and recommended action plans towards the future Tanzanian power system can be exploited at all governmental levels to achieve public policy goals and help develop business opportunities by motivating domestic and international investments in modernizing the nation's electric power infrastructure. In return, it should help build the green energy economy.

**Keywords:** Tanzania power grid; smart grid; infrastructure; green energy economy

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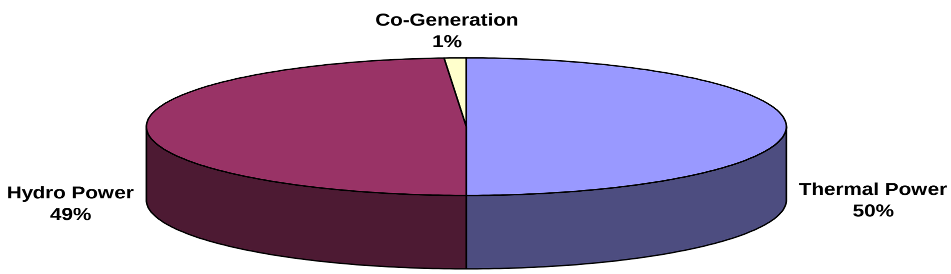
## 1. Introduction

The United Republic of Tanzania is the largest of the East African countries, bordered on the north by Kenya and Uganda, on the west by Rwanda, Burundi and the Democratic Republic of Congo, on the south by Zambia, Malawi and Mozambique, and on the east the Indian Ocean. Tanzania has a total area of 954,000 square kilometer with a population estimate of 46 millions, of which 80% lives in the rural area and 20% in the urban area. Electricity generation, transmission and distribution in Tanzania are undertaken by the Tanzania Electric Supply Company known as TANESCO. The total installed electricity capacity is 1129 MW, of which 50% is thermal, 49% is Hydro and 1% is co-generation (Figure 1). Distribution from power stations occurs via 2986 km of 220 kV transmission line, 1971 km of 132 kV lines, and 554 km of 66 kV lines. Currently 2% of the rural population and 39% of the urban population (10% of Tanzanian) have access to electricity, which leads to a peak demand of 1031 MW, while the available capacity has been dropped to 650 MW due to faulty generating equipment and prolonged drought. Therefore, there is a sizable challenge in mobilizing resources to implement new power generation and transmission projects, in order to meet the forecast annual growth of demand at roughly 9% according to the Power System Master Plan 2007–2031 study [1–3]. Tanzania has a per capital electricity consumption of 46 kWh per annum, which is growing at the rate of 11%–13% [1]. Hence the government is encouraged to expand generating capacity, transmission capacity, and distribution systems, and develop indigenous sources of energy. Provision of reliable energy is a critical function for the industrial and commercial sectors of any country [4]. In Tanzania however, the actual electrical energy sector falls short of the required level of reliability, although the country has an estimated 3800 MW of potential hydro capacity and abundant gas, coal, solar, wind and various biomasses that can be converted and used as cheap and sustainable sources of energy. Therefore, utilizing these resources will provide Tanzania with the opportunity to overcome these challenges. However, the limited financial power, lack of capital as well as other legal and administrative barriers constrain the infrastructural construction of new power plants and transmission lines.

**Figure 1.** Current source of electricity generation.



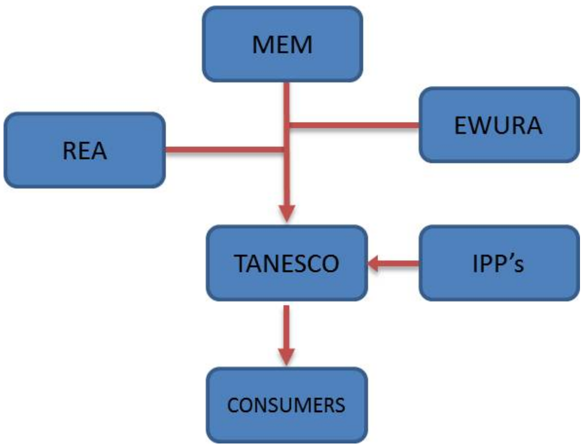

In this paper, we first provide an overview of Tanzania power along with its electricity industry structure in Section 2. Section 3 then outlines current challenges in the existing power systems. Section 4 explains the reason of using smart grid in Tanzania. In Section 5, some of the current initiatives undertaken by the Tanzania government in response are discussed. The roles of smart grid in meeting these challenges in the future and TANESCO's challenges in finding capital are discussed in Section 6. Finally, conclusions are drawn in Section 7.

## 2. Tanzania Electricity Industry Structure

The electricity sector in Tanzania is a vertically integrated structure carrying out generation, transmission, distribution and supply, with the state-owned public utility enterprise, Tanzania Electric Supply Company Limited (TANESCO), operating the grid.

The government, through the Ministry of Energy and Minerals (MEM), is responsible for formulating energy policy. Regulation of the sector is the preserve of the independent Energy and Water Utilities Regulatory Authority (EWURA) and the Rural Energy Agency (REA), and it has been charged with scaling up rural electrification. Due to slow development in the sector and the general global trend in the electricity supply industry, the government lifted the monopoly of TANESCO and allowed the involvement of the private sector known as Independent Power Producers (IPPs) in the electricity industry. Figure 2 presents the Tanzania electricity industry.

**Figure 2.** Structure of Tanzanias electricity industry.




### *2.1. Regulatory Arrangements*

The Electricity Act 2008 (the "EA") is the primary legislation for the generation, transmission and distribution sectors of Tanzanian electrical power. It also stipulates cross-border trade in electricity and rural electrification. Rural Energy Agency has been established to oversee the implementation of rural electrification projects, using the Rural Energy Fund as provided in the Rural Energy Act, 2005. The Energy and Water Utilities Regulatory Authority Act (Cap 414) (the "EWURA Act") establishes the EWURA to regulate the issuance, renewal or cancellation of the relevant licenses, determine the rates and charges of the services as well as monitor the performance of investment, quality and efficiency of the services with respect to regulated services. EWURA is also responsible for economic and technical regulation of the Tanzanian electricity industry.

### *2.2. Setting of Electricity Prices*

Like many other regulators, EWURA uses the internationally accepted revenue-requirement method (Equation 1) to determine electricity tariffs and adheres to the principles of tariff setting contained in Clause 23(2) of the Electricity Act [5].

$$RR = (RAR \cdot RoR) + E + D + T \quad (1)$$

where $RR$ is the revenue requirement, $RAB$ is the regulatory asset base, $RoR$ is the rate of return, $E$ is the operation and maintenance expenses, $D$ is depreciation, and $T$ is taxes.

TANESCO tariff categories and tariff are described in Tables 1 and 2, respectively.

**Table 1.** Tariff categories [6].

| Tariff categories | Description | Notes |
|---|---|---|
| D1 | This category covers domestic customers who on average have a consumption pattern for 50 kWh. The 50 kwh are subsidized by company and not subject to service charge. Under the category, any unit exceeding 50 kWh is charged a higher rate up to 283.4 kWh | Domestic low usage tariff (1-phase 230 V) |
| T1 | This segment is applicable for customers who use power for general purposes, including residential, small commercial and light industrial use, public lighting, and billboards. In this category the average consumption is more than 283.4 kWh per meter reading period | General usage tariff (1-phase 230 V or 3-phase 400 V) |
| T2 | Industrial consumers with monthly consumption greater than 7500 kWh and demand less than 500 kVA | Low voltage maximum demand (MD) usage tariff (supplied at 400 V) |
| T3 | Industrial consumers | High voltage maximum demand (MD) usage tariff (11 kV and above) |

**Table 2.** Tariff [6].

| Description categories | D1 | T1 | T2 | T3 |
|---|---|---|---|---|
| Low energy (0–50 kWh)—per kWh | 153.00 | | | |
| High energy charge per kWh (above 50 kWh) | 497.00 | | | |
| Service charge per month | | 3841.00 | 25,875.00 | 25,875.00 |
| Demand charge per KVA | | | 30,802.00 | 26,395.00 |
| Energy charge per kWh | | 400.00 | 240.00 | 212.00 |

Tariffs are in Tanzania Shillings (Tshs): 1 USD ≈ 1,600 Tshs as of August 2012.

## 3. Current Challenges in the Existing Power Systems

### *3.1. Generation*

The existing power system in Tanzania is divided into two distinct parts, the interconnected grid system and the isolated power system. There are currently about 1082 MW of installed capacity in the interconnected grid system and a further 21.6 MW of available capacity in its isolated grids. A further 15 MW of generation capacity is available through imports from Uganda and Zambia [7]. The interconnected grid system and isolated power system are summarized in Tables 3 and 4, respectively.

**Table 3.** Existing grid generation [2].

| Plant | Generation type/ownership | Installed capacity (MW) | Available capacity (MW) |
|---|---|---|---|
| Kidatu | Hydro/own | 204 | 200 * |
| Kihansi | Hydro/own | 180 | 180 * |
| Mtera | Hydro/own | 80 | 80 * |
| Newpanganifalls | Hydro/own | 68 | 66 * |
| Hale | Hydro/own | 21 | 17 * |
| Nyumbayamungu | Hydro/own | 8 | 8 * |
| Uwemba | Hydro/own | 1 | 1 |
| Songas | Gas/IPP | 202 | 185 |
| Ubungo wartsila | Gas/own | 102 | 100 |
| Tegeta wartsila | Gas/own | 45 | 42 |
| Tegeta IPTL | HFO/IPP | 103 | 100 |
| Symbion | IDO/IPP | 115 | 103 |
| Total hydro | | 562 | 552 |
| Total thermal | | 567 | 530 |
| Grand total | | 1129 | 1082 |

* depends on water level in the dams.

**Table 4.** Isolated generations [2].

| Name of plant | Number of unit | Max available capacity (MW) | Source of energy | Commissioned year |
|---|---|---|---|---|
| Tunduru | 4 | 1.000 | IDO/Gas oil | 1992 & 2008 |
| Kigoma | 14 | 9.200 | IDO/Gas oil | 1981–2010 |
| Ngara | 2 | 0.560 | IDO/Gas oil | 1991 |
| Mpanda | 4 | 1.840 | IDO/Gas oil | 1993 |
| Mbinga | 3 | 0.830 | IDO/Gas oil | 2000 & 2008 |
| Somanga | 3 | 5.000 | Natural Gas | 2010 |
| Songea | 6 | 3.150 | IDO/Gas oil | 1987/88, 2004/09 |
| Liwale | 3 | 0.287 | Gas oil | 2002/2003/2006 |
| Mafia | 2 | 0.424 | IDO/Gas oil | 1990 & 1991 |
| Biharamulo | 2 | 0.460 | IDO/Gas oil | 1991 |
| Kilwa Masoko | 2 | 0.750 | Gas | 1977 & 1999 |
| Masasi | 3 | 3.800 | IDO | 1985 |
| Ikwiriri | 2 | 0.436 | Gas | 1991 |
| Kasulu | 2 | 2.500 | IDO | 2011 |
| Kibondo | 2 | 2.500 | IDO | 2011 |
| Mtwara | 9 | 10.000 | Natural Gas | 2007 |
| Ludewa | 3 | 0.760 | IDO | 2008 |
| Total | 66 | 21.630 | | |

As discussed, Tanzania currently experiences a shortage of power supply due to its reliance on weather-dependent hydro-power source and increasing electricity demand, surpassing the present capacity of generation. This has recently caused more frequent and severe power outages.

### *3.2. Financial Aspects*

TANESCO currently experiences poor financial positions. Each of the main causes is discussed in the following subsections.

#### 3.2.1. High Transmission and Distribution Losses

Transmission losses in Tanzania continue to be among the highest in the world, and reducing losses or improving transmission efficiency is the main concern in the electric power sector. Since 49% of electricity is generated by hydro and all the hydro-power stations are located in the southern part of Tanzania while most load centers are in the northern part, the national grid is experiencing transmission and distribution losses of about 25% with frequent power outages [5]. High losses in the distribution systems are mainly due to the aging systems, with inadequate investments over the past years resulting in unplanned extensions of distribution lines and the overloading of system equipment such as transformers and conductors [8].

#### 3.2.2. Revenue Loss

High revenue loss in the Tanzanian power sector is mainly contributed by general inefficiency in management, poor billing system due to low metering accuracy, theft, corruption and unreliable power services. As a result, there is lack of investment in generation capacity, repair and maintenance program. This increased the load shedding and unplanned outages.

#### 3.2.3. High Tariff

Currently in Tanzania, tariff is very high due to high technical and nontechnical losses and scarcity of electricity. Most people hence are unable to afford electricity, driving the utility company to be financially sick and unable to invest more for the future load growth demand.

#### 3.2.4. Aging Infrastructure

Aging transmission and distribution infrastructure causes high transmission and distribution losses and drives the power system to be highly vulnerable. For example, since many of the protection equipment have not been thoroughly inspected and replaced for a long time (even many years), it is not uncommon to experience power outage due to false tripping of the aged circuit breaker.

### *3.3. Load Growth Outstripping Supply*

Current national maximum load demand is 1031 MW, very close to the installed generation capacity of 1082 MW. However, the average available capacity has been dropped to 650 MW due to prolonged drought, lack of spinning reserve (not infrequently with no reserve margin). The situation is expected to get worse according to the demand forecast of the country for the next 14 years to come, as presented in Table 5. If this forecast actualizes, it will require a triple of Tanzanias existing generation capacity in the next 14 years. Therefore, it is important for TANESCO to expand generation capacity to meet the load growth while reducing the losses and suppressing the load growth by providing various demand programs for improving energy efficiency.

**Table 5.** Demand forecast [2].

| Year | Demand forecast (MW) | Year | Demand forecast (MW) |
|---|---|---|---|
| 2012 | 1031 | 2019 | 2055 |
| 2013 | 1210 | 2020 | 2202 |
| 2014 | 1333 | 2021 | 2361 |
| 2015 | 1471 | 2022 | 2536 |
| 2016 | 1593 | 2023 | 2740 |
| 2017 | 1778 | 2024 | 2951 |
| 2018 | 1925 | 2025 | 3177 |

### *3.4. Environmental Impact*

Tanzania is experiencing widespread deforestation, which currently stands at 400,000 hectares per annum as a result of excessive use of fire-wood and charcoal, thus accelerating drought and desertification. This is because about 80% of the population lives in the rural areas with only 2% of them having access to the electricity. The remaining meets their energy requirements mostly by wood fuel and charcoal [9,10].

### *3.5. Interconnection with Neighboring Countries*

In order to stabilize power supply and facilitate export to neighboring countries, Tanzania became a member of the Southern African Power Pool (SAPP), though not yet interconnected. When the interconnection is done, it will provide a link between the Eastern Africa Power Pool (EAPP) and the SAPP linking Tanzania with Kenya in the north and Zambia in the south. But at the moment, the transmission system does not have adequate capacity to transfer power efficiently [11].

## 4. Why Smart Grid in Tanzania

Due to global need of energy conservation, carbon emission reduction, green energy, sustainable development, supply reserve margin, reduction of transmission and distribution losses, optimal utilization of assets, many countries are devoting time and resources to smart grid technologies.

The economic growth of developing countries like Tanzania depends heavily on the reliability, safety, cost effectiveness, high quality and efficiency of its electric power supply. However, Tanzania is struggling to meet its electricity demands, both in terms of energy and peak Load. This is due to the fact that Tanzania power system is desperate for a complete overhaul and upgrade of its current infrastructure, which involves installation of new intelligent equipment at all critical generation, transmission, distribution and consumption points. Pricing and billing systems would also need to be amended to ensure that everybody is paying their fair share and reduce electricity theft, corruptions and wasteful use. With this, it is expected that smart grid will change the conventional concept of energy management and operations in Tanzania power system. Some of the key requirements of the Smart Grid are summarized below [12]:

1. allow for the integration of renewable energy resources to address global climate change;
2. allow for better utilization of existing assets to address long term sustainability;

3. allow for optimized energy flow to reduce losses and lower the cost of energy;
4. allow for the management of distributed generation and energy storage to eliminate or defer system expansion and reduce the overall cost of energy;
5. allow for the integration of communication and control across the energy system to promote interoperability and open systems and to increase safety and operational flexibility;
6. allow for active customer participation to enable far better energy conservation.

## 5. Current Initiatives toward a Stronger, More Secure and More Efficient Smart Grid

To meet the increase in energy demand as projected in the Power System Master Plan, TANESCO needs to tackle the present problems first and then plan for significant new investment in generation, transmission and distribution assets. In line with the projection, the Tanzanian government recognizes that it is time to act on all those challenges in order to move toward a stronger, more secure and more efficient power grid. Efforts to do so are motivated by several goals with the aim to deliver electricity to customers reliably, safely, cost effectively and in a sustainable manner. Some of the initiatives taken and future plans are listed in Tables 6 and 7.

**Table 6.** Short term pilot project on generation [2].

| Year commissioned | Name of the project | Type | Additional capacity (MW) |
|---|---|---|---|
| 2012 | Ubungo Plant | Gas | 100 |
| 2012 | Mwanza | HFO | 60 |
| 2013 | Singida Wind Farm | Wind | 100 |
| 2013 | Kinyerezi CC | Gas | 240 |
| 2013 | Kiwira I | Coal | 200 |
| 2013 | Mnazi Bay Mtwara CC | Gas | 300 |
| 2013 | Somanga Fungu | Gas | 230 |

**Table 7.** Long term pilot project on generation/interconnection [2].

| Year | Name of project | Type | Additional capacity | Total installed capacity (MW) | Project demand (MW) | Project power pool (MW) |
|---|---|---|---|---|---|---|
| 2015 | Rusumo Falls | Hydro | 21 | 1682 | 1471 | 211 |
| 2015 | Interconnector I (Singida-Nairobi) | Import/Export | 200 | | | |
| 2016 | Ruhudji Hydro Project | Hydro | 358 | 2048 | 1593 | 455 |
| 2018 | Rumakali Project | Hydro | 222 | 2582 | 1925 | 657 |
| 2020 | Stieglers Gorge I | Hydro | 300 | 2882 | 2202 | 680 |
| 2021 | Interconnector II (Zambia-Tanzania) | Import/Export | 200 | 3082 | 2361 | 721 |
| 2023 | Stieglers Gorge II | Hydro | 600 | 3542 | 2740 | 802 |
| 2024 | Ngaka Coal Project | Coal | 400 | 3755 | 2951 | 804 |
| 2025 | Mchuchuma I&II | Coal | 400 | 4155 | 3177 | 978 |
| 2026 | Stieglers Gorge III | Hydro | 300 | 4455 | 3437 | 1018 |

*5.1. Energy Balance Mix*

With reference to Table 8, Tanzania is endowed with huge primary sources of energy such as water, coal, natural gas, uranium, wind, solar, biomass, *etc*.

**Table 8.** Tanzania energy resources [2].

| Resource | Potential | Power | Degree of exploitation |
|---|---|---|---|
| Hydro | 4700 MW | 4700 MW | 562 MW |
| Biomass | Sustained yield 24.3 million $m^3$ p.a | 26 MW | Use 40 million $m^3$ 91,276 hectare p.a. deforestation |
| Coal | 304 million tons | 1600 MW | 3 MW |
| Natural Gas | 64 billion $m^3$ | 500 MW | 361 MW |
| Wind | Speed: 7.6–9.9 m/s | 200 MW | Not exploited |
| Solar | 187 $W/mm^2$ | Approximately 215 $W/m^2$/day | 2 MW |
| Geo-Thermal | 650 MW | 650 MW | Not exploited |
| Uranium | Not assessed | | Not exploited |
| Tidal&Wave | Not assessed | | Not exploited |

Current plans and initiatives are called to fully exploit all available generation sources in order to have energy balance mix. To avoid high dependency on a hydro power source, the following projects have been initiated.

5.1.1. Mchuchuma Coal power

With the proven coal reserves, Mchuchuma coal mine for power stations in Ludewa district in southern Tanzania will be sufficient to fuel 1600 MW capacities for 30 years, or to fuel 400 MW capacities for 120 years for the grid after completion of the project [9]. In view of the above, this will also provide a reliable and sustainable source of power in east Africa for many decades to come.

5.1.2. Renewable Energy

With the new energy policy, independent power producers are allowed to generate electricity from different sources including wind and solar generation sources. The Singida wind power project has been the only wind power project up until now and it is expected to deliver 100 MW to the grid at the Singida substation by the year 2013. It is interesting to note that Tanzania government is implementing a National Solar Program under the World Solar Program (WSP). The WSP is an open-ended attempt through broad partnerships and cooperation of governments and NGO organizations to promote the wider utilization of renewable energy resources. So far the government has declared two of its five project proposals submitted to UNESCO as being of high national priority. These proposals are (1) village level solar electrification; and (2) small islands solar electrification. With these projects, the penetration level of solar power is expected to increase greatly.

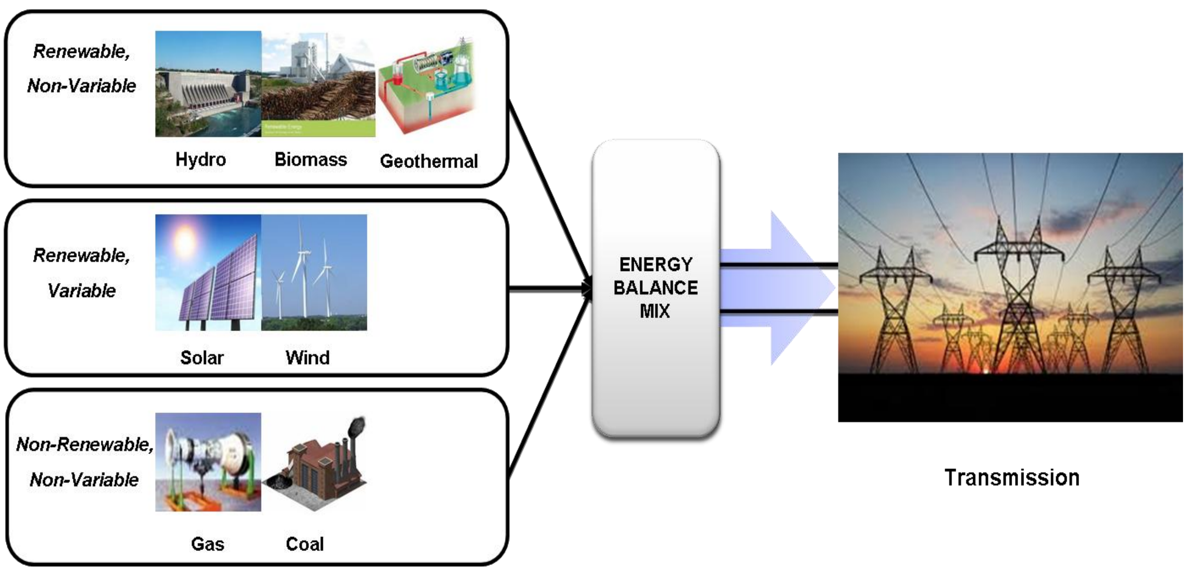
#### 5.1.3. Existing Hydro and Thermal Power

There is a plan to initiate efforts for life extension, upgrading and restoration of all existing hydro and thermal power plants for full exploitation of all their available resources, *i.e.*, 3800 MW hydro capacities potentially available. Therefore, in order to fulfill the future development aspiration of the country in line with National Development Vision 2025 towards a more secure, strong and smart power grid, a new energy policy is to be established. This policy should allow independent power producers to generate electricity from different sources including new and renewable sources of energy. The energy balance mix will be classified as shown in Table 9, hence it will be possible to generate electricity both from renewable and non-renewable energy sources in bulk quantities as shown in Figure 3. With that, the future security of electricity supply will be ensured.

**Table 9.** Energy balance mix generation categories.

| Category | Description |
|---|---|
| Variable | Generation from wind and sun, which can vary with time. |
| Non-Variable | Generation from continuous process, coal, water and biomass. |
| Renewable | Generation from a source that can be replenished, e.g., wind, water, biomass. |
| Non-Renewable | Generation from a source that cannot be replenished, e.g., coal or oil. |

**Figure 3.** Energy balance mix generation scenario.




### 5.2. Transmission Systems

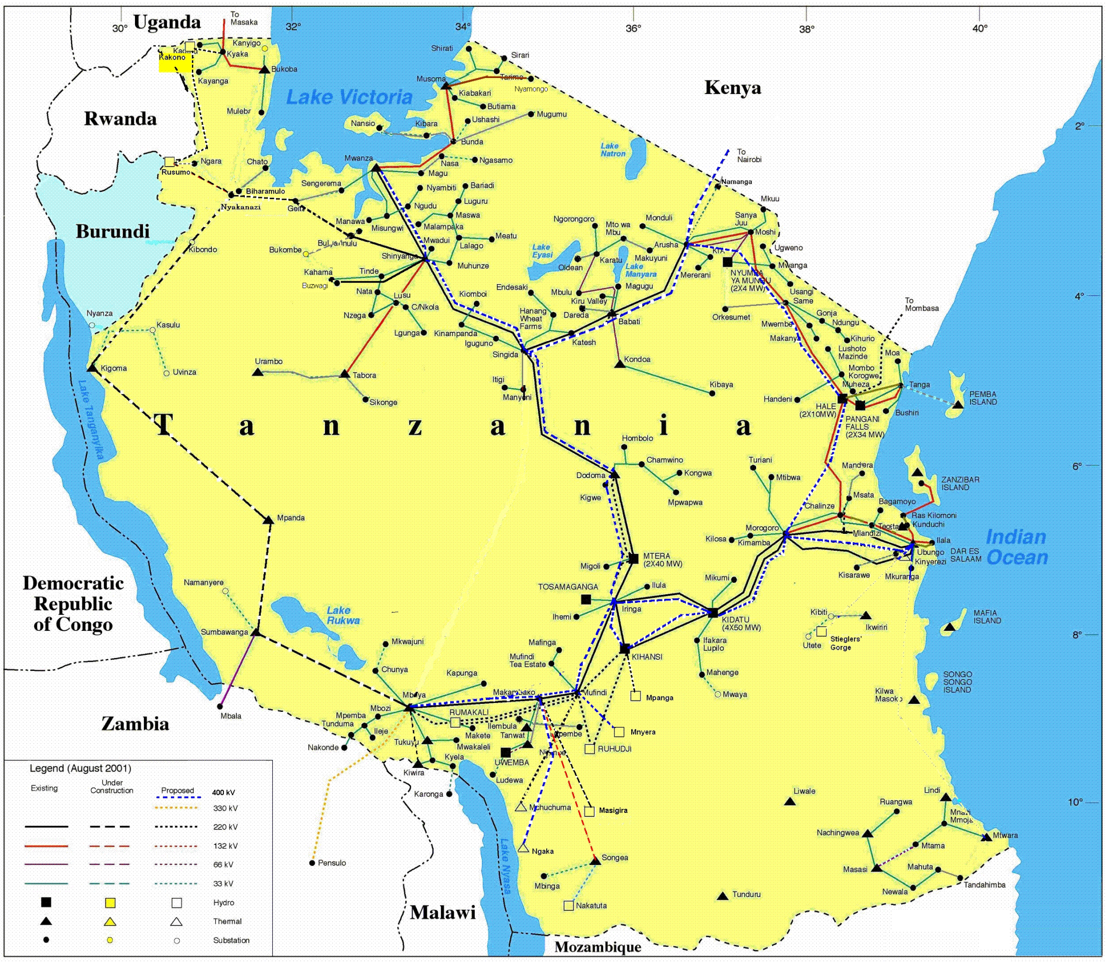
Transmission projects continue to be accorded as a high priority in the context of the need to transmit power from the generating stations to the load centers, through system strengthening and creation of a national grid. Therefore with regard to the present problem, plans are underway to upgrade/expand the grid transmission line and to install new HVDC lines as presented in Table 10.

**Table 10.** Long term pilot project on transmission Lines [2].

| Grid Transmission system additions | Year | Distance (km) |
|---|---|---|
| 132 kV Ubungo-Mtoni (Zanzibar) | 2012 | 46 |
| 132 kV Makambako-Songea | 2013 | 320 |
| 300 kV Mnazi Bay-Singida(DC Line) | 2013 | 1,000 |
| 400 kV Iringa-Shinyanga | 2013 | 647 |
| 220 kV Kiwira-Mbeya | 2013 | 100 |
| 220 kV Kinyerezi-Ubungo | 2013 | 15 |
| 400 kV Morogoro-Chalinze-Arusha | 2013 | 602 |
| 400 kV Singida-Arusha-Nairobi | 2014 | 320 |
| 400 kV Kasama-Mbeya-Iringa | 2015 | 540 |
| 400 kV Shinyanga-Mwanza | 2015 | 140 |
| 220 kV Bulyanhulu-Geita | 2013 | 100 |
| 220 kV Geita-Nyakanazi-Rusumo | 2015 | 228 |
| 220 kV Ruhudji-Mufindi | 2017 | 200 |
| 220 kV Ruhudji-Kihansi | 2017 | 150 |
| 220 kV Rumakali-Makambako | 2018 | 200 |

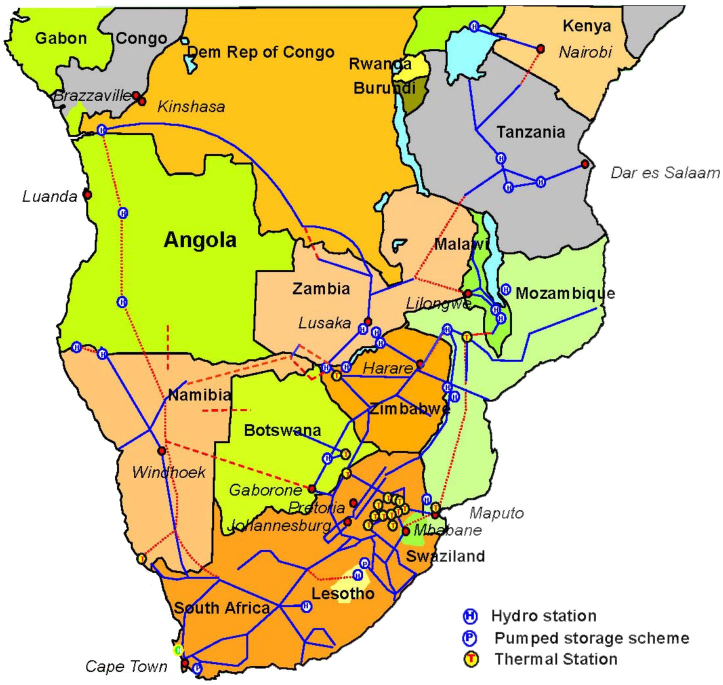
In particular, there is a new plan of installing a new HVDC transmission line for 667 km of 400 kV, 2000 MW capacities from Iringa to Shinyanga via Dodoma and Singida as shown in Figure 4.

**Figure 4.** Tanzania existing and future generation centers.



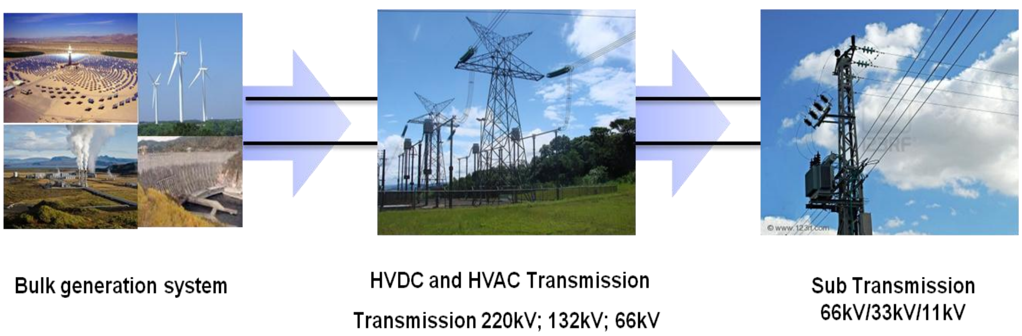
The HVDC transmission line from Iringa to Shinyanga will link existing and future generating sources in the southern regions of Tanzania to the load centers in the Mwanza and Arusha regions in northern Tanzania. Reasons for choosing HVDC include (i) cost-competitiveness with a lower voltage option; (ii) global standardization of the 400 kV double-circuit design; and (iii) a network planning rule-of-thumb that the next voltage level to be implemented should be on the order of 150–200 percent of the current highest system voltage [13]. Even though this HVDC transmission line can be installed on existing corridors, it will still entail substantial capital investment [7]. Also, with the aims to stabilize power supply and facilitate export to neighboring countries, this will facilitate power trade in the region by providing the critical link between EAPP and SAPP, as shown in Figure 5.

**Figure 5.** Southern Africa power pool.




On completion of that project, transmission capacity and power quality can be significantly improved while transmission losses are greatly reduced. The transmission network will further be monitored and controlled through Supervisory Control and Data Acquisition (SCADA) and EMS (Energy Management System), as depicted in Figure 6 below.

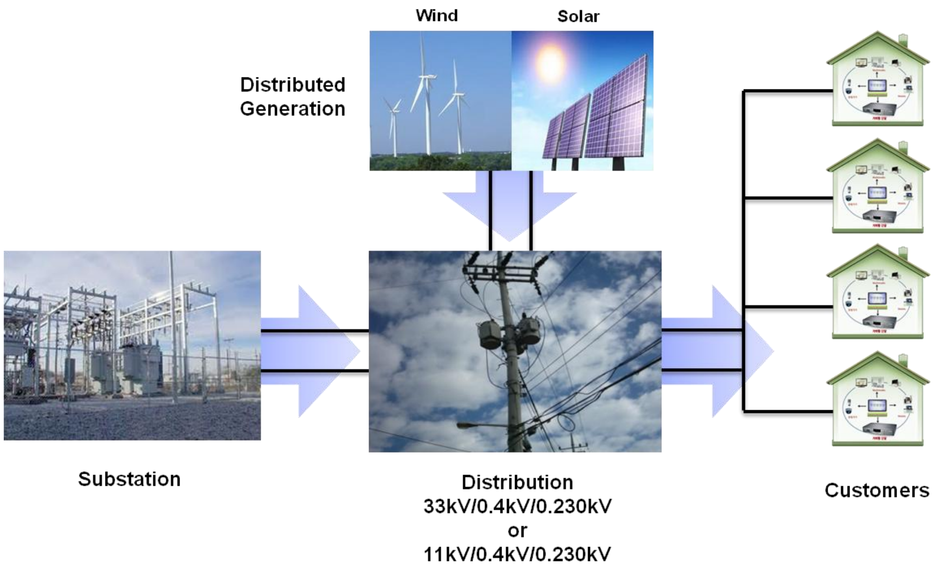
**Figure 6.** Transmission system scenario.



### *5.3. Distribution Systems*

The reliability of the distribution system depends on its structure and the degree to which they communicate with each other. In Tanzania, distribution systems are still radially configured with little telemetry, and almost all information exchanges within the system are performed by humans. The primary installed sensor base in this system is the customer with a telephone, whose call initiates the dispatch of a field crew to restore power. The current initiatives taken by Tanzanian government to modernize all sub-transmission and distribution systems should help in strengthening and reducing technical losses within the distribution systems. Therefore it is anticipated that the modern distribution system will be able to distribute the electricity to and from the end customers in a smart way where distribution network will connect the smart meters and all intelligent field devices and manage and control them through a two-way wireless or wired communication network. It may also connect to energy storage facilities and alternative distributed energy resources at the distribution level, as illustrated in Figure 7.

**Figure 7.** Distribution system scenario.




### *5.4. Loss Reduction Program*

#### 5.4.1. Technical Loss

TANESCOs transmission and distribution losses are significantly above acceptable industry standards. Its own internal Key Performance Indicator (KPI) targets are shown in Table 11.

**Table 11.** Distribution and transmission losses: actual and target losses (2012–2014) [5].

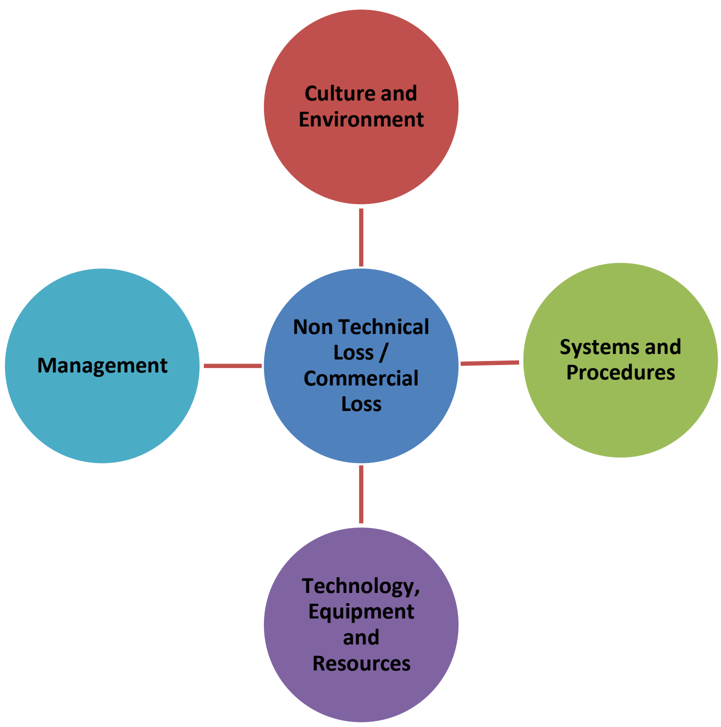
| **Energy losses** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** |
|---|---|---|---|---|---|---|---|
| Distribution losses (%Energy Fed into MV Network) | 18.0% | 19.7% | 19.7% | 18.5% | 17.2% | 15.9% | 14.6% |
| Transmission Losses (% of Generation) | 5.1% | 5.3% | 5.3% | 5.2% | 5.1% | 5.0% | 4.4% |

TANESCO has a loss reduction strategy that is coupled with the Capital Investment Program (CIP) distribution investments and improved Repair and Maintenance (R&M) expenditure. Despite its historical performance, TANESCO is aiming to achieve key transmission and distribution loss reduction targets in two ways. First, certain items within the CIP are allocated for reducing the energy losses within the transmission and distribution network. Secondly, increased expenditure on R&M will allow both the current and new asset base to be adequately maintained to help reduce transmission/distribution losses. While these may contribute to a significant upfront cost to TANESCO (either to be granted, financed or recovered directly through the tariff), the savings through a reduction in energy required to be generated will reduce upward pressure on the tariff through lower generation costs. Therefore, all things being equal, addressing loss reduction will result in lower generation requirements, which will lower the generation cost and reduce the likelihood of load-shedding. This will improve the revenue collections and enhance the financial position of TANESCO.

### 5.4.2. Non-Technical Loss and Commercial Loss

TANESCO faces various but interrelated problems of non-technical or commercial losses. TANESCO has thus identified main four elements that must be addressed as part of an integrated strategy program in order to mitigate commercial losses [14]. Figure 8 illustrates the interaction among these elements.

**Figure 8.** Non-technical loss and commercial loss elements.



Specific actions regarding each element to reduce the non-technical loss include:

Culture and Environment

1. Over a period, implement a staff awareness program combined with sanctions to combat the culture of corruption and collusion.
2. Implement a public awareness campaign to advise customers of the implications of electricity theft and to encourage "whistle blowers" to provide information.
3. Commence moves to have the legal powers strengthened to help secure convictions for electricity theft.

Systems and Procedures

1. Produce a comprehensive policy document on revenue protection to be communicated to all.
2. Ensure that payment channels are adequate to encourage convenient purchase of credit or payment of bills.
3. Develop a system of focused visits to premises where theft may be suspected.
4. Utilize meter readers to a much greater degree to report suspicious installations.

Technology, Equipment and Resources

1. Provide proper resourcing for revenue protection units, including personnel and Transport.
2. Consider the use of portable meter-testing equipment for on-site testing.
3. Pilot an extension of the split-meter concept (currently under consideration for AMR customers) to specific non-AMR customers.

Management

1. Undertake proper planning of revenue protection activity with short-term, medium-term and longer-term plans prepared at the appropriate levels.
2. Provide ethics and management development training for Revenue Protection Managers and for Zonal Managers in the future.
3. Ensure security or provide incentives to both staff and "whistle blowers".

Therefore, this integrated approach combined with the smart meter technology are expected to resolve the current challenges in non-technical loss.

### *5.5. Revenue Collection*

Since the government initiated some projects with the aim of increasing generation capacity, transmission capability, distribution services and rural electrification, it is expected that after completion of those projects together with improving metering efficiency, proper energy accounting, improved billing systems and collections, the reliability will be improved and number of customers connected will be increased, too. This will lead to increased revenue collections. These revenues will allow TANESCO to improve its financial position and to develop a system with an adequate reserve capacity margin that can support the development of future Tanzania power system in the most effective, competitive and sustainable manner.

### *5.6. Rural Electrification Policy*

Since majority of rural Tanzanians have no access to modern energy services, the government realized that rural Tanzania cannot be transformed into a modern economy and their lives cannot be improved significantly without a dramatic improvement in their access to modern energy services [15]. For this reason the government launched REA to promote and facilitate improved access to modern electrical energy services in rural areas. Also, the government set the National Energy Policy to ensure availability of reliable and affordable energy supplies and to promote efficient energy use in order to support national development goals. The policy recognizes that the main thrust has to be based on private initiatives and investments for exploitation of local energy sources. The policy sets an entirely new approach to the modernization of rural distribution system of Tanzania, and the government has committed itself to develop and implement the new strategy to address modern energy needs of over 80% of Tanzanians living in rural areas. The improved energy supply in the rural areas through public and private sector participation will contribute significantly to the livelihoods of the rural population and the attainment of sustainable economic growth. For these reasons, the Rural Energy Board (REB), REA, and the Rural Energy Fund (REF) were established and entrusted with the role of promoting, stimulating and facilitating improved access to modern energy services in rural areas through empowering both public and private sector initiatives in rural energy.

### *5.7. Customer*

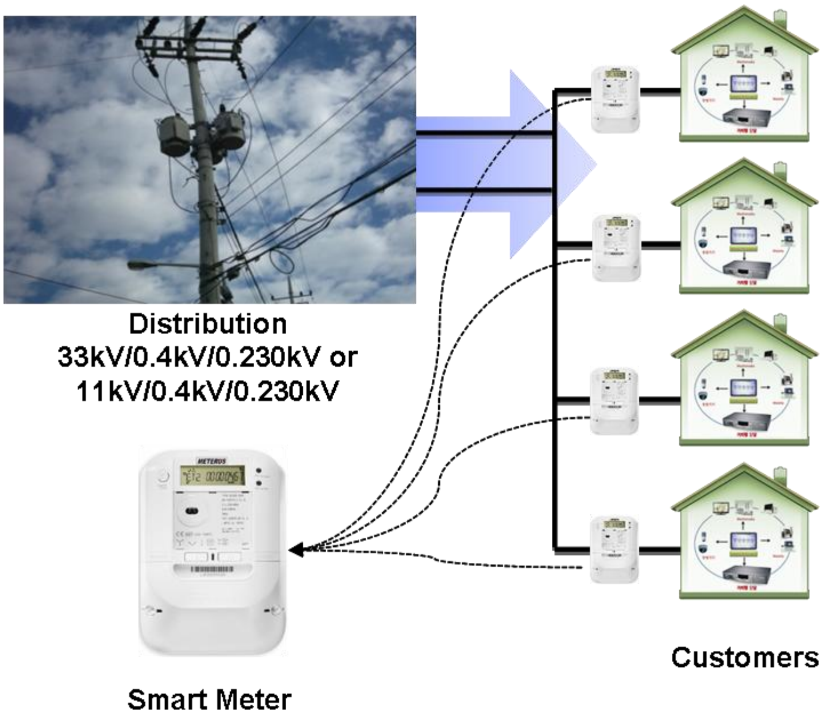
TANESCO has set a target to connect an additional 100,000 customers each year, providing further stimulus for growth. The combined annual growth rates provided in the Power System Master Plan (PSMP) 2009 to 2014 are listed in Table 12.

**Table 12.** Projected customer growth rates per annum (TANESCO PSMP) [5].

| Years | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| Customer Growth Rates per Annum | 12.1% | 16.9% | 10.8% | 9.7% | 10.5% | 12.7% |

With an increasing number of customers connected together with the introduction of smart meter technology in future power systems of Tanzania, it will be possible to come out with the customer scenario model as illustrated in Figure 9. In this scenario, the customer of the smart grid is where the end-users of electricity (home, commercial/building and industrial) are connected to the electric distribution network through the smart meters, because smart meters provide real-time information about electricity usage and cost to an in-home display or software application that allows customers to make informed choices about energy use and save their electricity cost [16,17]. Therefore, with this scenario, customers are becoming more proactive and are being empowered to engage in energy consumption decisions [12].

**Figure 9.** Customer scenario.




*5.8. Environmental Protection*

By currently promoting the use of energy balance mix, establishing the HVDC transmission line and establishing the rural electrification project that will address modern energy needs of over 80% of Tanzanians living in rural areas, the deforestation due to excessive use of fire-wood and charcoal can be curbed and the carbon emissions can be reduced, which is the urgent global priority [4,16].

## 6. Discussion

Across the globe, certainly in Tanzania there is surely an enthusiastic push to transform the existing electric power systems through smart grid initiatives. The smart grid may mean many things to different audiences, but the smart grid in Tanzania is envisioned to meet extraordinary economic and environmental challenges, critical needs for grid security, as well as energy sustainability. It may be characterized by its objectives as summarized in the following:

- Energy balance mix—the future security of electricity supply will be ensured.
- Smart transmission lines—the future transmission losses will be reduced, transmission capacity will be maximized and reliability and quality of grid power will be significantly improved.
- Smart distribution lines—the modern distribution system will be able to distribute the electricity to and from the end customers in a smart way, where distribution network connects the smart meters and all intelligent field devices and manage and control them through a two-way wireless or wired communication network. It may also connect to energy storage facilities and alternative distributed energy resources at the distribution level.

- Loss reduction program—the occurrence of load-shedding will be reduced. This will increase the revenue collections and the financial position to TANESCO.
- Revenue collection increases—this will allow TANESCO to improve its financial position, and therefore develop a system with an adequate reserve capacity margin that can support the development of future Tanzania power system in the most effective, competitive and sustainable manner.
- Rural electrification policy—there will be improved energy supply in the rural areas through public and private sector participation, which will contribute significantly in the livelihoods of the rural population and the attainment of sustainable economic growth.
- Behavioral changes in electricity consumption—customers will be more proactive and empowered to engage in energy consumption decisions affecting their day-to-day lives.
- Smart meters technology—the metering efficiency will be improved to enable proper energy accounting, improved billing systems and collections.
- Environmental protections—the deforestation due to excessive use of fire-wood and charcoal will be curbed and the carbon emissions will be reduced, which is the urgent global priority.
- Integrated approach (individual issues program)—the challenges that TANESCO faces in terms of non-technical loss (theft, corruptions, sabotages) will be addressed.

With all those taken into account in the Tanzania future scenario models, it is anticipated that smart grid will resolve TANESCO challenges and enable unprecedented opportunities for growth by transforming electric power infrastructure.

However, TANESCO faces a lot of challenges in finding capitals in order to refurbish and expand the system and increase access to electricity, because it has been operated mainly by getting capital from its revenue collection through tariff setting, grants fund and loan fund. Thus, the government has instructed EWURA to set tariffs adequate to meet cost of services of TANESCO and also to ensure that the utility expenditure goes well with its Cost of Service (COS) [5]. The implementation of these plans may be sufficient to cover the TANESCO COS and provide confidence to donors that TANESCO can meet its repayment obligation. For the aforementioned projects, the Tanzania government is scheduled to provide 32% of the grant funds and the Millennium Challenge Corporation (MCC) is anticipated to provide 26% of all grant funds. Additionally, Swedish International Development Cooperation Agency (SIDA) is projected to provide 12% and the REA 11%. World Bank funds through Tanzania Energy Development and Access Expansion Project (TEDAP) contribute 6%, Offiziersgesellschaft der Rettungstruppen Deutschschweiz (ORET) 6%, International Development Association (IDA) 4%, Japan International Cooperation Agency (JICA) 3% and the African Development Bank (AfDB) 0.3%. Also the Chinese government is projected to contribute 42% of all CIP loans primarily for the Kinyerezi, Kiwira and Mnazi Bay generation plants and high voltage transmission projects. World Bank IDA is estimated to finance an additional 31%, European Investment Bank (EIB) 31%, AfDB/JICA additional 30% and South Korea Economic Development Cooperation Fund (EDCF) 8% for the 400 kV Iringa Shinyanga transmission backbone [7].

## 7. Conclusions

With all the challenges that Tanzania faces in electric power sector, this paper has presented visions towards future Tanzanian power grid, and observations that the global smart grid initiatives should be taken in Tanzania to modernize the present power grid and boost the economy. This research has developed feasible scenarios to support planning and integration of the diverse components of the Smart Grid. The developed scenarios are envisioned to be a framework for the government at all levels to develop and evaluate public policy goals and business opportunities in modernizing the nation's electric power infrastructure and building a clean energy economy. They are also in line with Electrification Act of 2008 established by Tanzania government, which provides for facilitation and regulation of generation, transmission, distribution, transformations, supply and use of electric energy, and also provides for cross-border trade in electricity planning and regulation of rural electrification.

To realize the visions and scenarios, the action plans may further be recommended as follows:

- The Tanzania government should form an inter-ministerial committee to deal with integrated water resource management as a means of managing water crises in power generating dams.
- The Tanzanian government should invest more resources towards identifying sources of energy and encourage private investors to develop them for use.
- The Tanzania government should encourage and facilitate research in technologies aimed at promoting the power sector. In this respect R&D institutions, as a matter of priority, should be engaged in research to assist Tanzania in its efforts to diversify energy sources.
- The Ministry of Energy and Minerals in Tanzania should put in place a coordinating body to ensure efforts towards smart electric grid technology.
- Professional bodies in Tanzania should be involved in brainstorming on the power situation in Tanzania toward suitable energy balance mix for sustainable social-economic development.

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